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# The Impact of Digital Transformation on Perspectives of Sustainable Green Economy Development

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## Abstract

This article explores the convergence of digital transformation and sustainable development as two interrelated vectors of societal development in the 21st century. Sustainability is significantly impacted by the intertwined themes of environmental innovation and digital transformation. This study aims to clarify how environmental innovation and digital transformation affect sustainability. The study's methodology incorporates elements of a scoping review, grounded in a positivist perspective on the phenomena under consideration. Namely, how global issues, including resource depletion, social injustice, and climate change, can be addressed in several ways through environmental innovation and digital transformation. This study emphasizes how innovation and digital technologies must be included in environmental conservation initiatives. The implications of the systemic interactions between these vectors are outlined and analyzed, including their industry-specific dimensions. Particular attention is paid to the phenomenon of "twin transformation" and its role in the recovery process in post-conflict areas. The findings identify key patterns of the "digital green economy" as an emerging socio-economic formation and demonstrate that digital transformation serves as a critical enabler of international climate commitments, while also strengthening national socioeconomic resilience. Moreover, the study concludes that sustainable development and digital transformation must progress in tandem, ensuring the sustainability of digitization while advancing the goals of sustainable development.

## Keywords

Management; Digital technology; Green economy; Circular economy; Post-war sustainable development; Green transition

## Introduction

Attempting to increase the efficiency of the global economy and the economies of individual states is inextricably linked to sustainable development and the use of green economy principles. The greening of economic development has ultimately created a new science (branch of scientific knowledge). The green economy is based on the principles of the close relationship between current economic issues and ecology. At the same time, the current global economic landscape is marked by accelerated rates of digital transformation, which is shaping the development of the digital economy as the defining - socio-economic formation of the 21st century.

The digital and green economy sectors are currently undergoing a profound transformation. This shift is revolutionizing business models, technological innovation and adoption, application development and use, as well as information exchange between human and machine domains. Scholars in this field emphasize that innovation in environmental conservation and digital transformation are both necessary to create a sustainable economy. Global issues such as climate change, the loss of natural resources, and the social injustices humanity faces have the potential to be resolved by the interconnected developments in digital transformation and the green economy. Innovation is crucial in order to navigate the digital environment, take advantage of new business opportunities, and promote the adoption of circular economy models and principles (Oluleye, Chan and Antwi-Afari, 2023). Furthermore, the extensive incorporation of blockchain, cloud computing, artificial intelligence (AI), and other modern technologies into conventional production systems aids businesses in streamlining operations, cutting costs, boosting output, and developing flexible and effective operational frameworks (Krysovatyy *et al*., 2025; Lozo and Onishchenko, 2021; Quttainah and Ayadi, 2024).

A substantial body of contemporary literature affirms that digital transformation has a positive effect on promoting green development. Scholars have emphasized the vital role of digital transformation in enhancing the efficiency of a green economy model (Lyu *et al*., 2023). In terms of mechanisms of influence, several studies have demonstrated that digital transformation can enhance innovation efficiency through information technology, optimize industrial structure through “industrial digitization” (Yi *et al*., 2022), and reduce pollution emissions and energy consumption through the timely dissemination and monitoring of environmental data (Liu and Wang, 2022).

However, the relationship between the green transition and digital technology is complex and multifaceted. While the growing digitization of energy-intensive industries holds the potential to make many economic and social activities more sustainable and energy-efficient, this connection also presents challenges that require careful management. Digital technologies provide improved decision-making and optimization, which may be used to promote a green transition. For instance, artificial intelligence and the Internet of Things facilitate managing smart energy, increase energy efficiency in cities and buildings by using digital twins and smart sensors, for example, the ability to repair software-related product flaws remotely, and the potential to reduce e-waste. Through the use of tools that promote transparency, customers can actively participate in making more environmentally friendly decisions. In this way, digital technologies can also

support a beneficial systemic shift that could have a positive influence on the environment. However, some of the potential environmental benefits of digital technology may be offset by the increased energy and resource requirements associated with the production and use of information and communication technologies ICT. Digital technologies may harm the environment at every stage of their life cycle - from the extraction of rare earth resources used in their production, to the significant energy consumption of ICT components required for their operation, and ultimately to the pollution generated by electronic waste. Furthermore, particularly in metropolitan areas, the growing water and electricity demands of data centers can place a significant strain on local water resources and energy networks (Theofanidis, Abidi and Erturk, 2024).

As a result, digital transformation and the green economy are two crucial drivers that interact and correlate to define sustainable growth. Therefore, this interplay underscores the need for a holistic scientific approach to studying their interconnections. Specifically, Pricopoaia *et al*. (2025) demonstrate that leveraging the combined potential of digital transformation and environmental innovation can pave the way toward a more sustainable and prosperous future for coming generations. Recent technological advancements and innovations offer new opportunities to address climate-related challenges, environmental degradation, and the depletion of natural resources. While also increasing the efficiency of technological innovation can also provide a significant contribution to sustainable economic growth (Mohamed, Liu and Nie, 2022). Waste reduction, production process optimization, and resource consumption monitoring are all made possible by incorporating digital technologies into sustainability plans. Nonetheless, digital transformation is a significant undertaking that necessitates large financial and human resources for infrastructure improvements and technology adoption (Jones, Hutcheson and Comba, 2021).

According to Liu and Chen (2024), green growth is strongly associated with positive developments in the digital economy, while negative shifts in the digital economy are correlated with declines in green growth. With this in mind, this study aims to identify core patterns, concerns, and practical aspects of the correlations between digital transformation and green economy developments.

## Methods and Materials

The theoretical and methodological foundations of this study are shaped by the perspectives of academic scientific schools focused on the evolution and development of environmental economics, ecological economics, and sustainable development economics, as well as the digital economy. A schematic representation of the research paradigm and structure is presented in figure 1.

As a theoretical basis, the study draws on scientific perspectives regarding the current model of interaction between the green economy and the digital economy, specifically in the context of their combined impact on economic growth, with the context of sustainable development. This study employs a range of established academic research methods, including general scientific approaches such as induction, analysis, synthesis, and a systems-based perspective. It incorporates a dialectical view alongside positivist qualitative research. According to the selected positivist paradigm, reality is considered

objective and predetermined, with certain phenomena measurable regardless of the observer. Thus, the inductive strategy employed in this study aligns with positivist principles, wherein outcomes are shaped by empirical observations and the methods used to analyze them. Realism believes that science is the means of uncovering truth and attaining a sufficient understanding of the world to enable prediction and control. The scientific method, within this view, is a distinctive approach that allows identification of the cause-and-effect relationships that govern the functioning of observed phenomena.

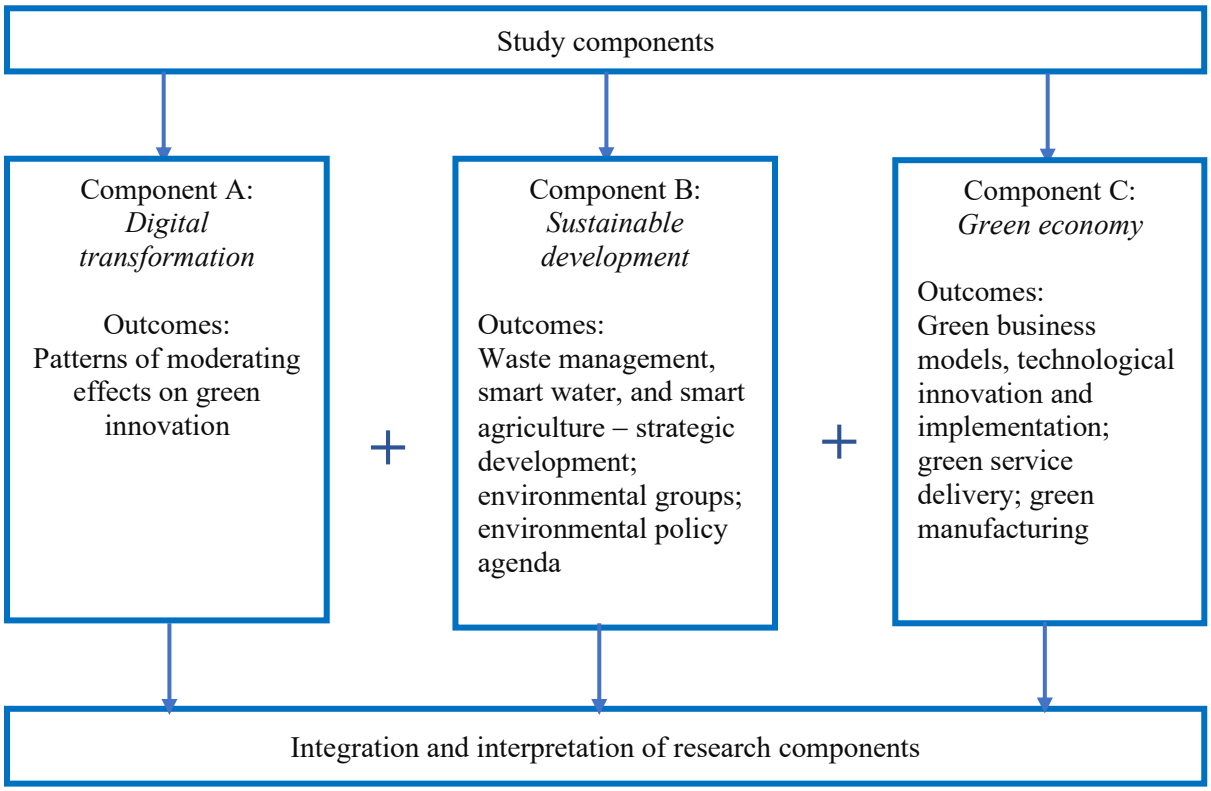
Study components
Component A: *Digital transformation*
Outcomes: Patterns of moderating effects on green innovation
+
Component B: *Sustainable development*
Outcomes: Waste management, smart water, and smart agriculture – strategic development; environmental groups; environmental policy agenda
+
Component C: *Green economy*
Outcomes: Green business models, technological innovation and implementation; green service delivery; green manufacturing
Integration and interpretation of research components

Figure 1: Research process schematic model

This study was conducted from a review-based perspective. Following the schematic model of the research process, each component involved a two-stage process. In the first stage, a literature search was performed focusing on the domains of digital transformation, sustainable development, and green economy. The search was conducted using JSTOR, ScienceDirect, Wiley, and MDPI databases facilitated by the AI-powered platform Scite. This platform enables searches across a mix of article metadata (titles and abstracts), as well as citation statements indexed from the full-text of research articles. In the second stage, the initial search results by Scite were then manually reviewed and analyzed using tools from grounded theory. The obtained categories were employed to guide a final round of literature selection. This refined sample served as the basis for the review, analysis, and alignment of findings within this study.

## Results and Discussion

### *Correlation and intertwining of digitalization and sustainability concerns*

The intersection of information and communication technology (ICT) and the challenge of environmental sustainability represents a central theme in contemporary discourse on the evolution of global economies and societies. In recent years, the digital economy and the green economy have emerged as the two most significant topics on the environmental policy agenda. Achieving a long-term equilibrium between environmental preservation and human development, a prerequisite for sustainable development, would greatly benefit from the use of technology (Souter *et al*., 2010). The late 1990s and the early 2000s witnessed a similar emphasis on the development of information and communication technology.

Green innovation and digital transformation are effective strategies for achieving carbon peaking, carbon neutrality goals, and superior economic growth. Using a sample of high-energy-consuming listed businesses from 2012 to 2021, Liu and Zhang (2024) built a double fixed-effect model to confirm the impact of green innovation on high-energy-consuming businesses' performance in reducing carbon emissions. They also used digital transformation as a moderating variable to examine the internal mechanism through which green innovation influences high-energy-consuming businesses in their reduction of carbon emissions under the influence of digital transformation. While digital transformation positively moderates the effect of green innovation on carbon emission reduction in this sector, the empirical results demonstrate that green innovation can also significantly improve the performance of these enterprises in reducing carbon emissions (Novikova *et al.,* 2021). When accounting for industry heterogeneity, digital transformation is found to have a significant moderating effect in sectors such as the manufacturing of chemical raw materials and chemical products, as well as in the production and supply of electricity and heat. However, the industries that are not yet significantly impacted by green innovation and digital transformation include petroleum processing, coking and nuclear fuel processing, non-metallic mineral products, ferrous metal smelting, rolling and processing, and non-ferrous metal smelting, rolling and processing.

### *International discourse*

The Paris and Glasgow conferences' broad agenda for sustainable development is built on overarching goals like "Green Growth" and "Green New Deal". However, there are differing views on how digital technology might contribute to green growth. The argument revolves around the topic of whether or not the entire economy's decrease in non-green energy usage due to digital technology is greater than its growth in non-green energy consumption.

EIT Digital (a Knowledge and Innovation Community supported by the European Institute of Innovation and Technology) examines four factors that affect how much energy digital technologies use: 1) their energy use; 2) the impact of digital technologies on overall energy efficiency, including rebound effects; 3) substitution driven by digital technologies; and 4) behavioral effects. One significant finding from this framework is that digital

technologies have a limited ability to contribute to the economy's total decrease in non-green energy. Digital technologies can intensify their efforts to employ renewable energy sources and improve energy efficiency, both within their operations and across the life cycles of their products. Nonetheless, the digital sector accounts for only 4-9% of the economy's total power consumption. In contrast, energy use in other industries is mostly determined by their specific activities, government policies, and potential (high or low-price elasticity relative to production elasticity). These dynamics are further affected by substitution effects, rebound effects, and behavioral impacts (EIT, 2022).

Conflicting narratives have emerged regarding the net effect of digital technologies on energy consumption, specifically, the balance between energy consumed by digital technologies and the energy savings they induce in other sectors. These divergent conclusions and estimates often lead to polarization rather than fostering discussion. Two primary factors contribute to this situation. First, there are legitimate concerns regarding the energy consumption of digital technologies, driven by the rapid growth in digital production and consumption as well as the accelerated pace of digital transformation due to the COVID-19 pandemic. Secondly, present efforts to reach definitive conclusions are hindered by persistent challenges in measurement and modeling issues that will require time and methodological refinement to resolve.

### *A "dark side" of digital transformation: view angle of sustainability*

Various studies emphasize that despite its many advantages, digital transformation can have a detrimental effect on sustainability due to resource depletion, increased energy consumption, and the production of electronic trash. These adverse impacts are exacerbated by the production of digital gadgets, data centers, and networks. Concerns regarding the social and ethical ramifications are also raised by the concentration of power in the hands of a few digital firms and the possibility of rising consumption habits (Agrawal, Srivastava and Sugiyama, 2024; Duporte, 2022; Goel, Masurkar and Pathade, 2024).

The current trend of excessive digital use, according to environmentalists, is unsustainable (The Shift Project, 2019). Digitization was referred to as a "climate disaster". As the headline of a 2018 study in Nature Climate Change reads, "Bitcoin emission alone could push global warming above 2°C" (Mora *et al*., 2018).

### *Energy efficiency impact*

Digital technologies, however, may have an impact on the efficiency of energy use in other sectors and in residential life through the three "Ds" (Sui and Rejeski, 2002): Demobilization (i.e., teleworking and teleconferencing instead of traveling); Dematerialization (i.e., e-books instead of printed books); and Decarburization (i.e., energy monitoring and management applications leading to less energy consumption). Additionally, digital technology enables virtualization, which includes more effective material handling, the decoupling of goods and services from material handling, and other resource-optimizing processes. Bieser and Hilty (2018) offer a more detailed categorization of digital technology applications, organizing them into seven categories (see Table 1). While significant research attention has been given to areas such as smart

buildings, smart energy, smart manufacturing, and shared products, the majority of research focuses on the application fields of virtual mobility, smart transportation, and virtual goods. Waste management, smart water, and smart agriculture are some less commonly evaluated sectors.

Table 1: Main application domains for Digital Technology energy efficiency (Bieser and Hilty, 2018)

| *Application Domain* | *Description* | *Example Use Cases* |
|---|---|---|
| Virtual goods | ICT-based services taking the place of tangible products | Online newspapers, music, video streaming, and e-books |
| Shared goods | Organizing product availability and boosting use | Platforms of sharing |
| Virtual mobility | Using ICT-based remote action to replace actual travel | Remote maintenance, distant learning, e-commerce, e-health, and video conferencing |
| Smart transport | ICT-enabled modifications to the way that people or products are transported | Traffic flow management and route optimization |
| Smart production | Changes in industrial processes and business models made possible by ICT | Production process automation |
| Smart energy | Applications of ICT in the energy industry, primarily in the provision of power | Smart demand-side management, distributed power generation, and smart metering |
| Smart buildings | ICT-enabled building management change | Intelligent (smart) lighting and heating |

Many evaluations use a product-oriented modeling method to examine how digital technologies alter manufacturing processes. Focusing on production systems enables a better understanding of the environmental impacts of a functionally equivalent system with and without the use of digital technology (Chaliuk *et al*., 2023). However, a shift in consumption patterns (such as individuals reading e-books rather than physical books) is considered an exogenous (external) variable. As a result, the consumption side is not given enough attention, despite the fact that both viewpoints are essential for fully understanding how digital technology might alter economic processes and their effects on the environment.

### *The innovation landscape*

Environmental groups and the digital sector tend to focus on different aspects of the two primary consequences of digitization. Industry focuses on (i) predicting that technological innovation will increase energy efficiency in the digital sector and (ii) demonstrating the potential of digitalization to reduce the energy consumption of other economic sectors, while also attempting to demonstrate that its energy consumption is currently lower than competing sectors (Komilova *et al.*, 2025). In contrast, environmentalists draw attention to the substantial energy consumption of the digital sector, particularly in energy-intensive applications such as video streaming and

blockchain technologies. Additionally, they emphasize the significance of rebound effects, whereby efficiency gains may lead to increased overall energy consumption and consumption of commodities (Gomez and Lorini, 2022).

As key shapers of policy and regulation, governments must deal with a challenging optimization issue that has several limitations. They cannot prioritize environmental sustainability above economic growth, but they also cannot prioritize the latter over the former. The majority of possible consequences involve challenging trade-offs and are surrounded by significant uncertainty. In these circumstances, within this complex landscape, a scenario approach could be expedient.

### *Core benefits of digitalization for sustainability*

Notwithstanding the aforementioned issues, there is ample evidence to support the positive correlation and convergence of digital transformation and sustainable development within the green economy, and digital transformation itself demonstrates its influence on sustainable development perspectives. Specifically, Wang and Kang (2024) assert that the digital economy's intrinsic "green" characteristics, such as lower marginal costs and less environmental impact, have given the industrial sector's green transformation new impetus. The authors use panel data for 283 Chinese cities at the prefecture level from 2011 to 2019 to investigate how the digital economy affects the green transformation of the industrial sector using a spatial econometric model. Using the Slack-Based Measure approach, Wang and Kang (2024) initially determined the extent of the green transformation in the industrial sector. According to a geographically based heterogeneity study, the digital economy is helping to greenify the industrial sector in both the eastern and central regions. According to the moderating effect analysis, industrial agglomeration and upgrading of industrial structures exert a significantly negative moderating effect. Furthermore, threshold effect tests show notable nonlinearities in the impact in the influence of industrial structure upgrading on the green transformation sector.

Particularly noticeable have been the beneficial externalities of the digital economy on the green transformation of the manufacturing sector. Unlike the traditional economy, the digital economy is characterized by networking, openness, and platformization. It leverages information technologies such as big data and the Internet, operating through a model driven by data, computing power, and algorithms. Through this model, temporal and spatial limitations may be overcome while simultaneously balancing intermittent renewable energy sources, such as wind and solar power, in real-time. The development of the digital economy has significantly raised the rate of resource consumption and production efficiency by enabling the movement of various resource elements. Additionally, it facilitates higher economic returns, increases decision-making efficiency, and aids in the intelligent operation of enterprises. Digital technology can effectively address financing issues in green sectors by facilitating and directing greater capital flows towards businesses adopting low-carbon technologies (Khatun, Sazzad, and Meghla, 2021). Digital technologies enable businesses to transcend geographical and temporal obstacles to learn new technologies and information internationally, advancing technological advancement through features like sharing and spillovers (Lo, Zhang and Xia, 2022).

### *Implications for agriculture*

Indeed, digital technology is playing an increasingly important role in shaping agriculture's response to climate change. For example, technological applications are assisting farmers in selecting drought-resistant crops, and tech-enabled early warning systems notify communities when storms are imminent. In addition to creating new opportunities for sustainable growth, the digital age is changing agricultural methods and proving invaluable in addressing global issues like environmental preservation and food security.

In order to meet humanity's long-term food and fiber needs while improving ecosystem health, sustainable agriculture uses holistic plant and animal production techniques (Xu *et al*., 2024). It is intended to decrease waste, preserve resources, and lessen the sector's negative effects on the environment. To preserve the natural resources essential for food production, farmers may improve soil fertility, preserve water supplies, and preserve ecosystems by implementing sustainable agriculture practices. Sustainable agriculture has changed over time in response to shifting social, economic, and environmental circumstances. The idea of sustainable agriculture, which was once centered on agroecology and organic farming (Schuster *et al*., 2023), has now broadened to include conservation agriculture (Stroud, 2020) and climate-smart agriculture, among others. Precision farming and digital agriculture are two examples of innovative techniques and cutting-edge technology that are integrated into sustainable agriculture to maximize output while reducing environmental impacts (Stoian *et al*., 2022).

Traditional agricultural methods and practices have been reshaped by the digital age, which has brought forth revolutionary opportunities for sustainable agriculture (Mushi, Di Marzo Serugendo and Burgi, 2022). The digital economy, digital infrastructure, information services, and agricultural technology (Barnes *et al*., 2019) are all part of the digital era, which encompasses a wide range of innovations and technologies that have the potential to improve the resilience and sustainability of farming systems. By incorporating digital solutions, sustainable agriculture increasingly benefits from numerous digital services and platforms. These include advancements in digital technology that allow farmers to monitor crop health, manage irrigation, and reduce chemical inputs, such as the Internet of Things, machine learning, remote sensing technologies, and geospatial analysis (Martos *et al*., 2021; Sishodia, Ray and Singh, 2020). By supporting climate-smart practices, digital technology integration in agricultural extension services improves farming communities' sustainability and resilience (Jones *et al*., 2023). Initiatives for digitally inclusive finance also give smallholder farmers access to financial services, allowing them to invest in environmentally friendly practices and adjust to shifting conditions (Zhao *et al*., 2022). Additionally, digital channels for rural household interaction improve rural communities' resilience and enable cooperative decision-making (Liu, Liu and Zhou, 2021).

By gathering, analyzing, and disseminating electronic data and/or information, Agriculture of Data seeks to enhance policy monitoring and evaluation capacities and aid in Europe's shift to sustainable agriculture (Hossain, Atibudhi and Mishra, 2023). In theory, this term can encompass any kind of data, including socioeconomic, agricultural and agronomy, space, and Internet of Things data gathered from commercial companies,

farmers, public authorities, and organizations (Swami, 2021). For Farm Management Information Systems (FMIS) to function effectively, all data and related information are necessary. Advanced technical solutions such as data integration, seamless connectivity, database interoperability, edge computing, and artificial intelligence can significantly enhance the functionality and effectiveness of FMIS services.

The goal of climate-smart agriculture (CSA) is to assist initiatives that support the shift of agri-food systems toward environmentally friendly and climate-resilient methods. Agriculture is widely regarded as the most vulnerable sector to the impacts of climate change, facing multiple and complex challenges. Maintaining stable crop yields and maintaining adequate food production and quality levels to continue meeting the growing demand of the world's population would require significant investment and creative solutions. Within the CSA framework, there are several strategies available, including the adoption of drought-tolerant crops, the reintroduction of autochthonous (locally adapted) crops to reduce environmental stress, particularly on water resources, optimizing water resources, and increasing wastewater reuse.

### *Green growth perspective*

Luo *et al*. (2022) used a random nonparametric data envelopment analysis model to evaluate the efficacy of green development, and a mediation model to examine the impact of the digital economy on the efficacy of green growth. They discovered that technological innovation, human capital growth, and industrial structure upgrading have been identified as some of the most important elements. Chen *et al*. (2015) examined how direct digital manufacturing differed from other conventional manufacturing paradigms in terms of green development. According to the study, direct digital production can lower the use of energy-intensive raw materials and transportation-related fuel, facilitating a more successful green manufacturing transition.

Digital transformation has proven to be a crucial facilitator in advancing international climate commitments in addition to enhancing national socioeconomic resilience. UNDP-supported nations are using technology in creative ways to step up their efforts to safeguard biodiversity, embrace renewable energy, and move toward a circular economy. Ecuador is specifically developing a digital traceability system to track commodities along the supply chain and monitor changes in land usage. Papua New Guinea has launched a mobile phone application to help law enforcement promptly document and report environmental damages, including unlawful logging and bush fires (Meddeb, 2022).

Calls for the implementation of responsible business conduct (RBC) in global value chains (GVCs) have been powerful drivers of economic growth and development in recent decades (OECD, 2021). Since the early 1990s, GVCs have transformed and accelerated international trade and investment by strengthening economic ties between countries and creating new opportunities for optimizing production processes through the implementation of digital technologies (OECD, 2017, 2021). According to a recent survey, many investors plan to double their sustainability-focused assets over the next five years, with the environment as a top priority (Blackrock, 2020). However, investors note that 'poor quality ESG data (Environmental, Social and Governance data) remains

one of the biggest obstacles to increased investment in this area' (Blackrock, 2020). Therefore, the development of digital technologies for measuring and monitoring the performance of businesses in terms of their ESG contribution can be an important step towards increasing trust in non-financial reporting and thus turning the growing interest of investors into real investment decisions.

Achieving a green recovery necessitates the integration of sustainable development principles into digital transformation processes, with the aim of fostering equitable digital access and literacy, promoting transparency and open data, and supporting innovations that enhance the efficiency of digital technologies while minimizing their environmental footprint (Pecheniuk *et al*., 2022). Digital tools are essential for fostering inclusive and environmentally friendly progress. However, their effective deployment requires a "whole-of-society" undertaking. Today, we are witnessing the emergence of a new socio-economic formation – digital capitalism, or what some refer to as a "digital green economy" (Paganetto, 2020). The concept integrates sustainable practices with digital technology to enhance economic growth while reducing negative environmental impact. In addition to establishing new green enterprises that utilize digital technology to maximize resource utilization and lower emissions, this framework aims to incorporate digital solutions into established green sectors, including waste management, sustainable agriculture, and renewable energy.

The idea of a "digital green economy" acknowledges how digital technology may help to achieve sustainability objectives, including cutting down on waste, increasing resource management efficiency, and lowering energy use. Smart grids, for instance, may minimize energy use by balancing supply and demand via the use of digital sensors and real-time data analytics, eliminating the need for carbon-intensive backup power plants. Overall, a digital green economy aims to foster sustainability, resource efficiency, and low-carbon development while opening up new avenues for economic expansion.

Shortly, several intriguing breakthroughs in the digital green economy are anticipated. The following illustrates several pertinent examples:

1. Renewable energy expansion: In the upcoming years, it is anticipated that the shift to renewable energy sources, such as solar and wind power, will continue. With the advancement of energy storage technologies like batteries and hydrogen fuel cells, some of the challenges with intermittent power sources will be alleviated.
2. Smart cities: It is anticipated that the pace at which digital technologies are incorporated into urban infrastructure will quicken, resulting in more livable, efficient, and sustainable smart cities. For instance, smart buildings may save waste and energy use, while smart traffic management systems can improve traffic flow, lowering emissions and congestion.
3. The circular economy, which seeks to reduce waste and encourage resource efficiency, is anticipated to gain momentum. Circular business models, such as product-as-a-service, where customers pay for access to goods rather than owning them outright, can be made possible in large part by digital technology frameworks.
4. Industrial decarbonization: Among the biggest producers of greenhouse gas emissions are the steel, cement, and chemical industries. In order to

accomplish impactful decarbonization, these industries must transition to low-carbon practices, such as carbon capture and storage and the use of renewable energy sources. These transitions may be facilitated and optimized with the use of digital technology.

5. Green fintech: It is anticipated that the growth of green financial technology (fintech) services, such as carbon offsetting and green bonds, would accelerate in practice. These services can facilitate the shift to a low-carbon economy and assist eco-focused investments in sustainable initiatives.

Some of the most promising solutions to the current environmental challenges the world is facing are based on the use of AI. Indeed, advancements in AI make sustainability possible in almost every area of the economy, including industries like steel and shipbuilding, agriculture, forestry, green finance, construction, and engineering. In order to achieve net-zero policy goals, applications like as digital twins and the Internet of Things are increasingly being used more and more in environmental modeling, forecasting, and climate projections.

Significant advancements in communications technology and economics signal the shift to a digital economy, which can be seen as a postindustrial economy. This model emphasizes that networks and information are more important than capital. It is well acknowledged that new technologies are significantly affecting social and economic relationships, as well as the environment, both positively and negatively. However, the expansion of sustainable development is impossible without international communication and information sharing (Ciocoiu, 2011). Information and Communication Technology (ICT) and the Internet are viewed in this context as both dangers to sustainable development and as opportunities to overcome development limits.

Overall, as we work to solve the pressing issues of climate change and resource depletion, the nexus of digital technology and sustainability is anticipated to produce many fascinating innovations in the years to come.

### *Experiences and cases*

Governments worldwide are seeking solutions that match the severity and urgency of the climate crisis. Digital technology is a key tool in this effort, transforming how people live, work, and interact. Additionally, these advancements are developing innovative approaches to climate change management. Digital technologies are increasingly guiding low-carbon development and national climate adaptation initiatives and strategies.

The Korean “New Deal” presents a noteworthy example of integrating digital transformation with sustainable development strategies. As illustrated by the UN Environment Program, it offers a schematic depiction of the Korean “New Deal” (see Figure 2). The initiative aims to green the economy by introducing digital services and strengthening social safety nets. This will be supported through fiscal stimulus and legal reforms to incentivize private sector participation. Investment will concentrate on green infrastructure, renewable energy, and the promotion of green industries, reinforcing climate action and advancing the transition to a green economy.

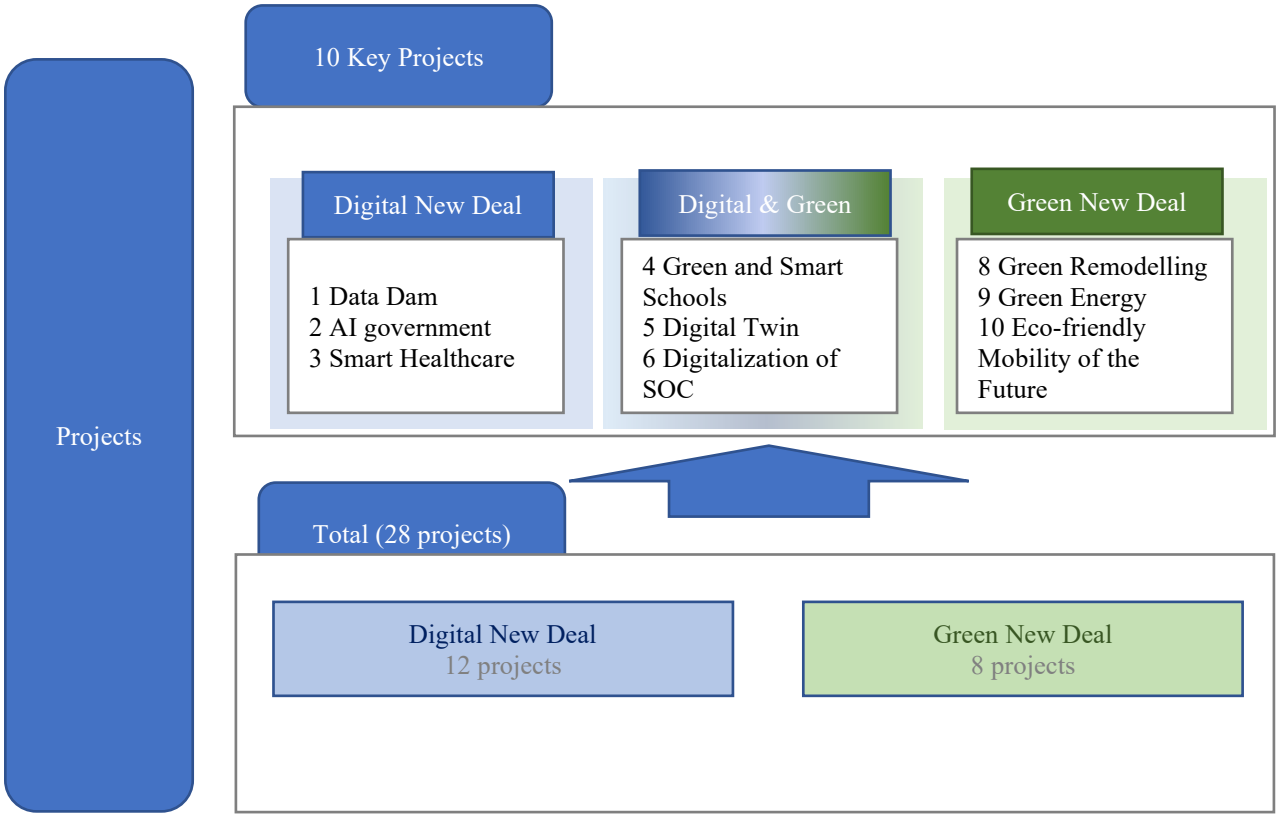


Figure 2: The Korean "New Deal" (National Strategy for a Great Transformation) [*Source*: Chen (2021)]

The Digital Transition and the Green Transition have become two mainstream development agendas in the EU. As the European Commission notes, 'These may seem like two separate issues, but they are dual challenges - neither can succeed without the other - and both are equally important for Europe's future' (EC, 2024). However, the European Commission pointed out the need to ensure that digital technologies do not consume more energy than they save. Currently, digital technologies account for 8 to 10% of energy consumption in the EU and 2 to 4% of greenhouse gas emissions. The European Commission proposes to focus on researching ways to reduce the environmental impact caused by the digital industry. One such area of improvement for the digital sector is a plan to provide climate-neutral, energy-efficient, and sustainable data centers by 2030 at the latest. The EU is also exploring voluntary and mandatory measures to help the private sector become climate-neutral and rely more on renewable resources. Some examples are the European Green Digital Coalition and various initiatives to green the audiovisual sector.

Additionally, as part of the European Green Deal priorities, the European Commission has proposed a Green Deal Industrial Plan to achieve climate neutrality by 2050, while increasing the competitiveness of Europe's zero-emission industry. A key element of the Industrial Plan is to ensure that the EU has access to the technologies, products, and solutions that are key to transitioning to zero emissions. These include photovoltaic cells, wind turbines, batteries, hydrogen electrolyzers, carbon capture, including storage

equipment, and more. Such products and solutions are also an important source of economic growth and provide quality careers in Europe.

To achieve this goal, the Plan outlines a process to accelerate investment and financing in cleantech manufacturing in Europe, putting the EU at the forefront of the cleantech revolution. The EU Industrial Plan is to be implemented through both existing funds and co-financing at the EU level. In March 2020, the European Commission also adopted a new Circular Economy Action Plan (CEAP). It is one of the main building blocks of the European Green Deal, Europe's new agenda for sustainable growth. The EU's transition to a circular economy will aim to reduce pressure on natural resources and create sustainable growth and jobs. This action plan is also a prerequisite for achieving the EU's climate neutrality target by 2050 and halting biodiversity loss.

The European Union has already taken the necessary steps to ensure sufficient financial access for the EGD implementation. The EGD Investment Plan envisages funding streams totaling €1 trillion. As part of this plan, the Just Transition Facility will mobilize at least €100 million of investment in the regions most affected by the green and digital transition. The use of bank guarantees to leverage other public and private investments is an important component of the EGD's investment plan.

Overall, the world is undergoing a green transition and rapid digitalization. Green transition is demonstrated by nations modifying their development plans to include measures for lowering carbon emissions, bolstering green technology, and switching to renewable energy. COVID-19 catalyzed digitalization, and nations have continued using digital technology across a range of economic sectors (Quimba *et al*., 2023). The emergence of Industry 4.0 has highlighted the diverse ways in which technology may impact human existence. However, these two economic influences (green transition and digitalization) should not be viewed as distinct forces but rather as coexisting elements that nations must manage to guarantee sustainable growth (Liubchych et al., 2023). Digital technology is increasingly being used in green transition plans to guarantee resource efficiency. However, in order to lower the energy consumption of digital transactions and infrastructure, digitalization necessitates the usage of renewable energy. The green transition and digitization frameworks are two transformations that nations of all income levels are currently undergoing.

However, a more strategic approach is needed to develop, facilitate, scale, and deliver solutions, especially to the most climate-vulnerable communities. Furthermore, this is particularly important for post-war recovery programs, where aligning digital and green (sustainable) growth can create more resilient systems. Yet, according to a study by the Global Recovery Observatory at Oxford University, supported by the United Nations Environment Program (UNEP), less than 20% of total recovery spending is allocated to environmental priorities (Langer and Brown, 2016). The primary goal of economic rehabilitation in war-torn areas is to set their economies on a path towards sustainable development. The Karabakh region of Azerbaijan has been severely impacted by armed conflict in recent decades. The proposal includes innovative strategies, such as "smart villages" and "agro-parks," to support sustainable development, guarantee food security, and modernize the agricultural and agro-industrial sectors.

Other authors argue that a green recovery in the Western Balkans requires comprehensive energy sector reforms to make the region healthier, more livable, and more attractive for return and investment (OECD, 2022a). Their argument draws on the example of the post-war Balkans, where some areas have not yet fully recovered from the war conflicts of the 1990s. In the long term, pursuing a more environmentally friendly, sustainable path for the area could unlock broader regional transformation. Beyond reforming the energy sector itself, the next stages will need to include a shift toward resource-efficient production methods and the development of entirely new manufacturing and service industries. Achieving this long-term vision of a greener future will require modernization across many sectors, along with strong links to education and skills development to drive change, spur innovation, and create next-generation business and employment prospects. Part of the funding needed for a transition to a green recovery framework in the Western Balkans is supported by the Economic and Investment proposal for the region, a EUR 9 billion initiative approved by the European Commission on October 6, 2020. To facilitate this transition, the strategy seeks to accelerate the region's long-term economic recovery. Moreover, the significance of initiatives to establish a digital highway throughout the Western Balkans is increasingly recognized as a key enabler of regional connectivity and development. While the Balkans are often associated with images of conflict and strife, countries in Southeast Europe are now collaborating on the digital front to construct a robust broadband network. This initiative aims to connect millions of people, foster innovation, and drive economic progress (Gelvanovska-Garcia, 2023). Additionally, the planned project will assist in the digitalization of the business sector, further the digitization of public services, and aid in the development of digital skills among the region's governments, enterprises, and citizens across the region. Key future priorities include addressing financial and infrastructure gaps in the digital sector, developing digital ecosystems and a Regional Digital Area, and expanding financing options for small business digitization. Epifani and Bartolini (2021) emphasize that broad cooperation among Western Balkan stakeholders, including public institutions and civil society, is essential to advancing digitalization and building trust in digital services. Such collaboration will help bridge the digital divide, improve access to essential services for all citizens, and support progress toward achieving the Sustainable Development Goals (SDGs).

In a world marked by conflict and destruction, new concepts for rebuilding cities are emerging. Advances in technology are opening opportunities to create more sustainable, integrated, and culturally responsive urban environments. Although there have been many unsuccessful attempts at post-war reconstruction efforts throughout history, the 21st century offers promise for renewed potential through ideas that are aligned with sustainability, integration, community engagement, and culture. Importantly, residents who are both the primary stakeholders and key actors in modern conflicts are deeply connected to the landscapes being rebuilt (SOHR, 2020). As the nature of conflicts evolves, so too must the methods used in post-war reconstruction in areas devastated by conflict. AI has recently become an essential tool in post-war city mapping, offering precise data to guide rebuilding efforts. When combined with digital architecture and cultural preservation, these technologies have the potential not only to restore what was lost but also to enhance human well-being and shape urban development in the future. Relying on pre-existing urban fabric instead of creating new plans from the start, AI can produce valuable data to assist policymakers in creating development plans for post-war

reconstruction that keep the integrity of the initial foundations of a city. One example is the "Re-coding Post-War Syria" initiative, which is using cutting-edge technology to provide data, including 3D scanning, to assess the current shattered urban fabric and identify the regions that require reconstruction. Notwithstanding, data collection for this initiative included the human element, which is crucial to this endeavor. In this instance, residents and refugees were consulted about their recollections of the past infrastructures and their hopes and predictions for the future. The inclusion of citizens in design choices also builds resilience and connection within the community. The project becomes fully integrated when the data is expanded to include more than just geometrical information (SOHR, 2020).

### *Ukrainian context*

In the context of Ukraine's post-war recovery, the OECD proposes the concept of Build Back Better, which envisions structural changes in the areas of (OECD, 2022b) innovation, science, and R&D. This strategy aims to address insufficient funding challenges and ensure the use of innovation and digital technologies in post-war recovery. Furthermore, Ukraine's recovery plans and strategies use the principle of Build Back Greener at various levels. For example, in July of 2022, the OECD (2022c) recommended that infrastructure should be rebuilt to meet three policy goals: sustainability, environment, climate change, biodiversity, inclusivity - social, geographic, age, gender, and generational; growth - efficiency, and increased competitiveness.

The paradigm of twin transformation forms the foundation for post-war sustainable development. This concept suggests leveraging innovation and digital technologies to drive sustainable action. Rapid action is essential for sustainability in this era of addressing several global environmental concerns, including climate change. Twin transformation, which suggests promoting sustainable growth via digitization, is important at this juncture.

Ideally, the digital and green transitions should be mutually reinforcing. For example, distributed ledger technology, such as that in blockchain and cryptocurrencies, can be applied to material traceability to improve recycling and maintenance efforts and advance the circular economy. To fully realize the benefits of the twin transition, a proactive and integrative approach will be required. While the private sector is expected to lead the digital transition due to its significant economic potential, active involvement and civil society will be crucial to mitigate negative consequences and amplify its positive contributions to environmental sustainability.

## Conclusion

The rise of the digital economy is driving profound global transformation, with digital transformation emerging as a crucial component for nations pursuing high-quality development. Effectively guiding green and sustainable innovation requires navigating the complex intersection of digital transformation and policy orientation. In light of the urgent need to move beyond outdated growth models marked by high energy consumption, huge emissions, and significant pollution, it is essential to build a

modernization paradigm in which humanity coexists harmoniously with nature. Steering businesses toward sustainable and green development has become a shared priority for both academia and policymakers. Across sectors, from industrial production to agriculture, energy, and urban planning, digital transformation offers powerful tools to support sustainable development, with many tangible successes already observed. Yet, digital transformation is a double-edged sword. While digital technologies present unique, practical opportunities for promoting sustainable growth, they also carry risks if misused or poorly regulated. Potential social and environmental harms must not be overlooked. Therefore, it is essential that digital transformation and sustainable development advance in tandem: the former must actively enable the latter, while the sustainability of both must be safeguarded through intentional design, regulation, and inclusive governance.

## References

Agrawal, R., Srivastava, A. and Sugiyama, A. (2024). *Sustainability in Digital Transformation Era: Driving Innovative & Growth: International Conference on Sustainability in Digital Transformation Era: Driving Innovative & Growth*. Florida, USA: CRC Press.

Barnes, A.P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T. and Gómez-Barbero, M. (2019). Exploring the adoption of precision agricultural technologies: A cross-regional study of EU farmers. *Land Use Policy,* 80: 163-174. DOI: https://doi.org/10.1016/j.landusepol.2018.09.005.

Bieser, J.C. and Hilty, L.M. (2018). Assessing indirect environmental effects of information and communication technology (digital technologies): A systematic literature review. *Sustainability,* 10(8): 2662. DOI: https://doi.org/10.3390/su10082662.

Blackrock (2020). *BlackRock Survey Shows Acceleration of Sustainable Investing*. Available online at: https://tinyurl.com/2svk5hbj [accessed on 30 June 2024].

Chaliuk, Y., Pohrishchuk, B., Kolomiiets, T., Yaremko, I., Hromadska, N. (2023). Modeling the application of anti-crisis management business introduction for the engineering sector of the economy. *International Journal of Safety & Security Engineering,* 13(2): 187-194 DOI: https://doi.org/10.18280/ijsse.130201.

Chen, Y. (2021). Digital transformation for an inclusive green economy. *UN Environment Program.* Available online at: https://tinyurl.com/5aks6n38 [accessed on 30 June 2024].

Chen, D., Heyer, S., Ibbotson, S., Salonitis, K., Steingrímsson, J.G. and Thiede, S. (2015). Direct digital manufacturing: Definition, evolution, and sustainability implications. *Journal of Cleaner Production,* 107*:* 615-625. DOI: https://doi.org/10.1016/j.jclepro.2015.05.068.

Ciocoiu, C. (2011). Integrating digital economy and green economy: Opportunities for sustainable development. *Theoretical and Empirical Researches in Urban Management,* 6(1): 33-43. Available online at: https://tinyurl.com/ms7kcn2a [accessed on 30 June 2024].

Duporte, A. (2022). Environmental impacts of digitalization: What to bear in mind. Aeidl, Policy Unit. Available online at: https://tinyurl.com/y3tjyu32 [accessed on 30 June 2024].

EC (2024). *Green digital sector*. European Commission, Brussels. Available online at: https://digital-strategy.ec.europa.eu/en/policies/green-digital [accessed on 30 June 2024]

EIT (2022). *Digital technologies and the green economy*. Available online at: https://tinyurl.com/4wyyhfd8 [accessed on 30 June 2024].

Epifani, S. and Bartolini, D. (2021). *Digital sustainability: Why digital transformation is the road to sustainability.* Institute for Digital Transformation.

Gelvanovska-Garcia, N. (2023). From conflict to cooperation: Building a digital highway across the Western Balkans. *World Bank Blogs*. Available online at: https://tinyurl.com/nseyutnh [accessed on 30 June 2024].

Goel, A., Masurkar, S. and Pathade, G.R. (2024). An Overview of Digital Transformation and Environmental Sustainability: Threats, Opportunities, and Solutions. *Sustainability,* 16(24): 11079. DOI: https://doi.org/10.3390/su162411079.

Gomez, J. and Lorini, M. (2022). *Digital transformation for sustainability: ICT-supported environmental socio-economic development.* London: Springer.

Hossain, M., Atibudhi, H. and Mishra, S. (2023). Agricultural Vulnerability to Climate Change: A Critical Review of Evolving Assessment Approaches. *Grassroots Journal of Natural Resources,* 6(1): 141-165. DOI: https://doi.org/10.33002/nr2581.6853.060107.

Jones, E.O., Tham-Agyekum, E.K., Ankuyi, F., Ankrah, D.A., Akaba, S., Shafiwu, A.B. and Richard, F.N. (2023). Mobile agricultural extension delivery and climate-smart agricultural practices in a time of a pandemic: Evidence from southern Ghana. *Environmental and Sustainability Indicators,* 19: 100274. DOI: https://doi.org/10.1016/j.indic.2023.100274.

Jones, M., Hutcheson, S. and Comba, J. (2021). Past, present, and future barriers to digital transformation in manufacturing: A review. *Journal of Manufacturing Systems,* 60: 936-948. DOI: https://doi.org/10.1016/j.jmsy.2021.03.006.

Khatun, L., Sazzad, R., and Meghla, N. (2021). Assessment of Open Spaces Ensuring Socio-Environmental Quality in Bogura Town, Bangladesh. *Grassroots Journal of Natural Resources,* 4(2): 77-90. DOI: https://doi.org/10.33002/nr2581.6853.040206.

Komilova, N., Ravshanov, A., Makhmudov, B., Murtazaeva, G. and Khakimov, O. (2025). Ecological Aspect and Prospects of Sustainable Development of Regions. *Grassroots Journal of Natural Resources,* 8(1): 355-379. DOI: https://doi.org/10.33002/nr2581.6853.080114.

Krysovatyy, I., Semenenko, Yu., Maslosh, O., Alboshchii, O. and Avedyan, L. (2025). Role of innovation parks in driving digital advances and promoting energy efficiency. *Grassroots Journal of Natural Resources,* 8(1): 37-60. DOI: https://doi.org/10.33002/nr2581.6853.080102.

Langer, A. and Brown, G. (Eds.) (2016). *Building sustainable peace: Timing and sequencing of post-conflict reconstruction and peacebuilding*. Oxford: Oxford University Press.

Liu, H. and Chen, D. (2024). Asymmetrical impact of natural resources and the digital economy on green growth in the top five Asian knowledge-based economies. *Resources Policy,* 88*:* 104525. DOI: https://doi.org/10.1016/j.resourpol.2023.104525.

Liu, X. and Zhang, Y. (2024). Digital transformation, green innovation, and carbon emission reduction performance of energy-intensive enterprises. *Scientific Reports,* 14(1): 3905. DOI: https://doi.org/10.1038/s41598-024-3905.

Liu, S. and Wang, Y. (2022). Green innovation effect of pilot zones for green finance reform: Evidence of quasi natural experiment. *Technological Forecasting and Social Change,* 186(A): 122079. DOI: https://doi.org/10.1016/j.techfore.2022.122079.

Liu, Y., Liu, C. and Zhou, M. (2021). Does digital inclusive finance promote agricultural production for rural households in China? Research based on the Chinese family database (CFD). *China Agricultural Economic Review,* 13(2): 475-494. DOI: https://doi.org/10.1108/CAER-05-2020-0075.

Liubchych, A., Savchuk, O., Vrublevska-Misiuna, K., Tychyna, V. (2023). Review of public environmental interests in Ukrainian contexts. *Grassroots Journal of Natural Resources,* 6(2): 4-18. DOI: https://doi.org/10.33002/nr2581.6853.060202.

Lo, K.L., Zhang, J. and Xia, F. (2022). Does digital technology innovation work better for industrial upgrading? An empirical analysis of listed Chinese manufacturing firms. *Applied Economics Letters,* 30(18): 2504–2509. DOI: https://doi.org/10.1080/13504851.2022.2087203.

Lozo, O. and Onishchenko, O. (2021). The Potential Role of the Artificial Intelligence in Combating Climate Change and Natural Resources Management: Political, Legal and Ethical Challenges. *Grassroots Journal of Natural Resources,* 4(3): 111-131. DOI: https://doi.org/10.33002/nr2581.6853.040310.

Luo, K., Liu, Y., Chen, P.F. and Zeng, M. (2022). Assessing the impact of digital economy on green development efficiency in the Yangtze River Economic Belt. *Energy Economics,* 112: 106127. DOI: https://doi.org/10.1016/j.eneco.2022.106127.

Lyu, Y., Wang, W., Wu, Y. and Zhang, J. (2023). How does digital economy affect green total factor productivity? Evidence from China. *Science of The Total Environment,* 857(2): 159428.

Martos, V., Ahmad, A., Cartujo, P. and Ordoñez, J. (2021). Ensuring agricultural sustainability through remote sensing in the era of Agriculture 5.0. *Applied Sciences,* 11(13): 5911. DOI: https://doi.org/10.3390/app11135911.

Meddeb, R. (2022). How digital can drive a green recovery. *UNDP*. Available online at: https://www.undp.org/blog/how-digital-can-drive-green-recovery [accessed on 30 June 2024].

Mohamed, M.M.A., Liu, P. and Nie, G. (2022). Causality between Technological Innovation and Economic Growth: Evidence from the Economies of Developing Countries. *Sustainability,* 14(6): 3586. DOI: https://doi.org/10.3390/su14063586.

Mora, C., Rollins, R.L., Taladay, K., Kantar, M.B., Chock, M.K., Shimada, M. and Franklin, E.C. (2018). Bitcoin emissions alone could push global warming above 2°C. *Nature Climate Change,* 8(11): 931-933. DOI: https://doi.org/10.1038/s41558-018-0321-8.

Mushi, G.E., Di Marzo Serugendo, G. and Burgi, P.Y. (2022). Digital technology and services for sustainable agriculture in Tanzania: A literature review. *Sustainability,* 14(4): 2415. DOI: https://doi.org/10.3390/su14042415.

Novikova, O., Pankova, O., Chaliuk, Y. and Kasperovich, O. (2021). The potential of digitalisation and social dialogue in ensuring post-pandemic labour market

sustainability: priorities for Ukraine. *Studies of Transition States and Societies,* 13(2): 70-85. DOI: https://doi.org/10.58036/stss.v13i2.954.

OECD (2017). How to make trade work for all. *OECD Economic Outlook*, 2017(1): 2. Available online at: https://www.astrid-online.it/static/upload/oecd/oecd-economic-outlook-ch2_june-20171.pdf [accessed on 30 June 2024].

OECD (2021). *Building more resilient and sustainable global value chains through responsible business conduct*. Available online at: https://tinyurl.com/4xhmhm82 [accessed on 30 June 2024].

OECD (2022a). A *green recovery in the Western Balkans. In Multidimensional review of the Western Balkans: From analysis to action*. OECD Publishing. DOI: https://doi.org/10.1787/f6bc363b-en.

OECD (2022b). *Build back a better innovation ecosystem in Ukraine*. Available online at: https://tinyurl.com/mryedr9u [accessed on 30 June 2024].

OECD (2022c). *The architecture of infrastructure recovery in Ukraine*. Available online at: https://tinyurl.com/m533jezu [accessed on 30 June 2024].

Oluleye, B., Chan, D. and Antwi-Afari, P. (2023). Adopting Artificial Intelligence for enhancing the implementation of systemic circularity in the construction industry: A critical review. *Sustainable Production and Consumption,* 35: 509-524. DOI: https://doi.org/10.1016/j.spc.2022.12.002.

Paganetto, L. (2020). *Capitalism, global change and sustainable development*. London: Springer. DOI: https://doi.org/10.1007/978-3-030-43071-3.

Pecheniuk, A., Mushenyk, I., Korzh, N., Mazurkevych, I., Oliinuk, N. (2022). Foreign direct investment as an indicator of environmental policy. *Grassroots Journal of Natural Resources, 5*(3): 49-62. DOI: https://doi.org/10.33002/nr2581.6853.050304.

Pricopoaia, O., Cristache, N., Lupașc, A. and Iancu, D. (2025). The implications of digital transformation and environmental innovation for sustainability. *Journal of Innovation & Knowledge,* 10(3): 100713. DOI: https://doi.org/10.1016/j.jik.2025.100713.

Quimba, F., Serafica, R., Bayudan-Dacuycuy, C., Andrada, A. and Moreno, N. (2023). Green and digital: Managing the twin transition toward sustainable development (PIDS Discussion Paper Series No. 2023-21). Philippine Institute for Development Studies (PIDS).

Quttainah, M. and Ayadi, I. (2024). The impact of digital integration on corporate sustainability: Emissions reduction, environmental innovation, and resource efficiency in the European. *Journal of Innovation & Knowledge,* 9(3): 100525. DOI: https://doi.org/10.1016/j.jik.2024.100525.

Schuster, J., Hagn, L., Mittermayer, M., Maidl, F.X. and Hülsbergen, K.J. (2023). Using remote and proximal sensing in organic agriculture to assess yield and environmental performance. *Agronomy,* 13(7): 1868. DOI: https://doi.org/10.3390/agronomy13071868.

Sishodia, R.P., Ray, R.L. and Singh, S.K. (2020). Applications of remote sensing in precision agriculture: A review. *Remote Sensing,* 12(19): 3136. DOI: https://doi.org/10.3390/rs12193136.

Souter, D., MacLean, D., Okoh, B. and Creech, H. (2010). *ICTs, the internet and sustainable development: Towards a new paradigm.* International Institute for Sustainable Development, Canada. Available online at: http://www.iisd.org/pdf/2010/icts_internet_sd_new_paradigm.pdf [accessed on 30 June 2024].

Stoian, M., Dobre, I., Popescu, C.G., Vasile, M.C., Dimitriu, A.T. and Ion, A. (2022). Increasing sustainability of food production and ensuring human health through agriculture digitalization. *Economics of Agriculture,* 69(4): 1209–1223. DOI: https://doi.org/10.5937/ekoPolj2204209S.

Stroud, J.L. (2020). Earthworms in no-till: The key to soil biological farming. In: Y. Dang, R. Dalal and N. Menzies (eds.), *No-till farming systems for sustainable agriculture: Challenges and opportunities* (pp. 267-280). London: Springer.

Sui, D.Z. and Rejeski, D.W. (2002). Environmental impacts of the emerging digital economy: The e-for-environment e-commerce? *Environmental Management,* 29(2): 155–163. DOI: https://doi.org/10.1007/s00267-001-0017-8.

Swami, S. (2021). Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India. *Grassroots Journal of Natural Resources,* 4(2): 136-150. DOI: https://doi.org/10.33002/nr2581.6853.040210.

SOHR (Syrian Observatory for Human Rights) (2020). The Fundamental Role of AI in Current Post-War Reconstruction. Available online at: https://www.syriahr.com/en/162801/ [accessed on 30 June 2024].

Theofanidis, F., Abidi, O. and Erturk, A. (2024). *Digital transformation and sustainable development in cities and organizations*. IGI Global.

The Shift Project (2019). *Lean ICT: Towards digital sobriety*. Available online at: https://theshiftproject.org/wp-content/uploads/2019/03/Lean-ICT-Report_The-Shift- Project_2019.pdf [accessed on 30 June 2024].

Wang, H. and Kang, C. (2024). Digital economy and the green transformation of manufacturing industry: Evidence from Chinese cities. *Frontiers in Environmental Science,* 12. DOI: https://doi.org/10.3389/fenvs.2024.1324117.

Xu, J., Li, Y., Zhang, M. and Zhang, S. (2024). Sustainable agriculture in the digital era: Past, present, and future trends by bibliometric analysis. *Heliyon,* 10(14), e34612. DOI: https://doi.org/10.1016/j.heliyon.2024.e34612.

Yi, M., Liu, Y., Sheng, M. and Wen, L. (2022). Effects of digital economy on carbon emission reduction: New evidence from China. *Energy Policy,* 171: 113271. DOI: https://doi.org/10.1016/j.enpol.2022.113271.

Zhao, P., Zhang, W., Cai, W. and Liu, T. (2022). The impact of digital finance use on sustainable agricultural practices adoption among smallholder farmers: Evidence from rural China. *Environmental Science and Pollution Research,* 29(26): 39281–39294. DOI: https://doi.org/10.1007/s11356-022-19970-2.

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*Authors' Contributions (in accordance with ICMJE criteria for authorship)*

| *Contribution* | *Author 1* | *Author 2* | *Author 3* | *Author 4* | *Author 5* | *Author 6* |
|---|---|---|---|---|---|---|
| Conceived and designed the research or analysis | No | No | No | Yes | No | No |
| Collected the data | No | No | Yes | No | Yes | Yes |
| Contributed to data analysis & interpretation | Yes | Yes | No | Yes | No | No |
| Wrote the article/paper | Yes | No | No | No | No | No |
| Critical revision of the article/paper | No | Yes | No | Yes | No | No |
| Editing of the article/paper | No | Yes | No | No | No | No |
| Supervision | No | Yes | No | No | Yes | Yes |
| Project Administration | Yes | No | No | No | No | No |
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The author(s) solemnly declare(s) that this research has not involved the plants for experiment and field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

*Research Involving Local Community Participants (Non-Indigenous) or Children*
The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

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